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Aquatic Plant Management

Alberta
ENVIRONMENT

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Alberta
ENVIRONMENT
Environmental Protection Services
Pollution Control Division
Pesticide Chemicals Branch

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I. INTRODUCTION

Surface waters form the basis for a wide variety of human activities. Lakes, reservoirs and rivers are used for recreation, fish production, and for domestic and industrial purposes. Farms throughout the province store water in open dugouts for human and livestock use. Over 1,000,000 acres (400,000 hectares) of agricultural land in southern Alberta are irrigated with water distributed by an extensive reservoir and canal system.

The growth of aquatic vegetation is a factor which, under certain circumstances, could impair the usefulness and aesthetic quality of a body of water. This becomes increasingly inportant as the quantity of water available for use becomes limited. When aquatic vegetation becomes a problem, there are steps that can be taken to restore the affected water body to a useful state.

Techniques available for aquatic plant management exist in various forms, each form having it's own particular application. This manual identifies some of these techniques and describes background information necessary for their safe and effective implementation.

Most of this manual is devoted to chemical control methods, because these are often the most effective and economical and therefore, are more often used. In addition, use of chemicals for aquatic plant management requires particular regard to procedure and safety so that undesirable consequences are avoided.

II. THE NATURE OF AQUATIC PLANTS

An aquatic plant can be simply defined on the basis of where it occurs. It's entire life cycle, from seed to flower, can be spent at least partially submerged in water. Terrestrial plants, on the other hand would be hard pressed to survive any substantial length of time under water.

Like terrestrial vegetation, aquatic plants germinate from seed or spores, undergo a growth phase, produce seeds or spores and then die back as winter approaches. A few aquatic plants may be annuals living for one season and reproducing from seed, however, most are perennials living indefinitely and reproducing by rhizomes, tubers or winter buds, as well as by seed.

A. BENEFICIAL ROLE

Aquatic plants play an important role in a lake, pond, or river environment. Rooted forms of aquatic vegetation help stabilize soil, thus preventing erosion of shoreline areas and reducing disturbance of bottom mud (hydrosoil). Erosion of shoreline soil increases turbidity and adds nutrients to the water creating undesirable water quality for fish production. During heavy winds, unstabilized lake hydrosoil may become stirred up creating turbid conditions. Suspension of rich organic soils in the water may lead to dissolved oxygen depletion which is hazardous to fish populations.

Aquatic plants add oxygen to the water during the process of photosynthesis. Oxygen in the water is essential to the survival of fish and other aquatic organisms and aids in the breakdown of organic pollutants through chemical and biological means.

Aquatic vegetation provides an important basic food source for the existance of aquatic animal life. Plant matter is fed upon by zooplankton and aquatic insects which are in turn fed upon by fish. Many birds and mammals also depend upon aquatic plants as a food source. Aquatic vegetation also provides nesting sites, breeding areas, and shelter against predation and adverse climatic conditions.

B. DETRIMENTAL ROLE

Certain species of aquatic vegetation may be induced to undergo such rapid and prolific growth that their beneficial nature can be lost. This takes place if environmental conditions are favourable, such as an excess of nutrients or a lack of natural controls (predators, parasites, or competing species). Prolific growth of aquatic vegetation becomes detrimental when it interferes with man's use of a water body or it threatens the existence of animals or plants which cohabit the aquatic environment.

Some of the problems associated with the overabundant growth of aquatic weeds are:

In Lakes and Ponds:

- interfere with or effectively prevent recreational activities such as fishing, boating, swimming, or water skiing
- alter feeding activity of game fish by sheltering food organisms
- cause winterkill of fish by depleting oxygen levels through decay processes under ice cover
- plug water intakes

- reduce shoreline property values
- provide breeding sites for certain insect pests
- certain forms of algae impart bad taste and odor to water; others cause severe oxygen depletion following mass die off by blooms during summer, and still others release toxic substances into the water

In Irrigation and Drainage Channels:

- reduce carrying capacities resulting in water shortages downstream and overflowing of banks
- reduce flow rates resulting in increased siltation and increased water losses due to evaporation and seepage
- plug intake screens and sprinkler heads

III. ENVIRONMENTAL FACTORS INFLUENCING THE GROWTH OF AQUATIC PLANTS

Under ideal circumstances (which seldom occur in nature) an aquatic environment exists in a state of slowly changing balance. Over time, a lake or pond will age, through erosion and consequent shallowing, until it eventually fills in and becomes dry land. This process takes hundreds to thousands of years.

A system of balances exists among plant, animal and microbial populations in the aquatic environment. This system works to correct any tendency for one population to flourish at the expense of others. It also ensures that the aging process remains gradual.

If the balance is tipped through some change in the aquatic environment, the survival of a certain species may be favoured over another. The favoured population may thrive causing others to decrease in number or disappear entirely. For example, if a factor necessary for the survival of a plant eating fish were removed from a system, two major effects could be seen due to the resulting imbalance. The fish would disappear and the plants on which it fed would flourish because a major control on their survival is no longer present. This uncontrolled plant growth would have undesirable consequences for other members of the aquatic community.

If a foreign organism is introduced to a system, it could cause problems because controls on its growth, which are present in its previous home, are absent in the new one. Similarly, in newly constructed canals or reservoirs, natural checks and balances do not initially exist; therefore, pioneering organisms (often weeds) gain a strong foothold.

The growth of aquatic vegetation is negatively and positively influenced by a number of environmental conditions. In a balanced system, these conditions act to keep aquatic plant growth at desirable levels. If one or more of these conditions change so as to favour growth, and if natural inhibitions do not compensate, the result will be an overabundance of aquatic plants. Overabundant aquatic plant growth results in problems for man and nature, and accelerates the aging process of water bodies.

Included among the environmental factors that influence aquatic plant growth are:

Sunlight

Sunlight is required as an energy source for photosynthesis, hence food production and growth. Water depth and clarity influence the amount of sunlight reaching submersed species, therefore, will limit the depth at which they will grow. The amount of sunlight required varies between species so that each species will have a maximum depth that it can inhabit.

Nutrients

Nutrients including nitrogen and phosphorus are necessary for the growth and development of aquatic plants. Rooted aquatic plants absorb nutrients from the hydrosoil. Submersed, free floating plants and algae are able to remove nutrients from the water column. Nutrient sources include decaying organic matter in the hydrosoil and water. Runoff from fertile lands and effluent from sewage plants or industrial areas also contribute nutrients to a water body.

Dissolved Gases

Aquatic plants use carbon dioxide and oxygen for food production and metabolism. The presence of these gases in water is of particular importance for plants that grow entirely beneath the water surface.

Water Temperature

Water temperature influences the rate of photosynthesis and metabolism, hence growth and development. Within limits, particular to species, warm water favours aquatic plant growth.

Bottom Type

The texture and composition of the hydrosoil are important in determining the successful establishment of rooted aquatic plants. Sand, clay, or gravel are generally low in nutrient composition and are therefore not conducive to plant development. Medium textured soils with high nutrient content are good for plant establishment and growth.

Parasites, Competitors, Predators, and Pathogens

These components of the aquatic environment act as natural control agents on the growth and development of aquatic plants. Plants introduced from foreign areas often become weeds because these controls are not present in the new environment.

STUDY QUESTIONS

1. Name four beneficial things that aquatic plants do.
2. Name two problems aquatic plants cause in irrigation canals.
3. What are three environmental factors that can encourage the growth of aquatic plants?
4. Name two sources of nutrients for aquatic plant growth.

IV. AQUATIC PLANT IDENTIFICATION

Identification of aquatic plants is based on the shape and structure of leaf, flower and stem, as well as notation of growth habit and location within the aquatic system. Often, identification to the species level requires the use of a microscope or at least a magnifying glass and reference to an identification textbook. Identification can be made easier, if one is aware of what general category a particular aquatic plant belongs to.

Common aquatic plants can be divided into two main groups: the algae and the aquatic macrophytes. These two groups can be further divided into categories based on growth habit and general structure.

A. ALGAE

Algae are single cells or aggregates of cells which do not possess true leaves, stems, roots or flowers. They are considered plants because they carry on photosynthesis. Individual algae can vary in size, some being microscopic while others are easily visible to the naked eye. There are three basic categories of algae.

1. Planktonic Algae - These exist freely in the water column as single cells or clumps of cells. They appear as tiny specks or small grass clippings - green, blue green or brown in colour. Under a "bloom" situation, some species impart a pea soup character to the water. Certain species are responsible for imparting bad taste and odour to water as they die off, while others may produce toxins, rendering the water poisonous. Rapid decay of dying algae blooms may deplete the water of enough oxygen to cause summerkill of fish.

   Examples: Aphanizomenon, Anabaena

2. Filamentous Algae - These algae are long, stringy and hairlike, and are often attached to rocks, larger aquatic plants or other surfaces under water. Stringy masses of filamentous algae may inhabit the bottom during cooler weather and rise to the surface as a bubble-filled scum during warm sunny weather.

   Examples: *Cladophora*, *Spirogyra*

3. Macrophytic or Branching Algae - These are larger forms of algae, that at first glance, resemble certain species of aquatic macrophytes. They are branched, coarse in texture due to a crusty coating of mineral deposits, and have whorled leaf-like structures. Macrophytic algae can form thick beds on the bottom and when brought into the air they give off a fishy or skunk-like odour.

   Examples: *Chara*, *Nitella*

B. AQUATIC MACROPHYTES

These are aquatic plants, other than algae, that are large enough in size to be seen with the naked eye. The vast majority of aquatic macrophytes possess leaves, stems, roots, and flowers. There are four general categories of aquatic macrophytes.

1. Free Floating - These plants exist at or near the water surface and are not attached to the bottom or any submerged object. They are freely moved about by wind and wave action.

   Examples: duckweed, bladderwort, liverwort

2. Submersed - These are rooted or attached plants which are completely submerged, except for flowering structures in some species. Many spread by rhizomes and produce tubers or buds which enable survival under adverse conditions, such as

desiccation, or ice cover during winter. Submersed plants are most abundant at depths of 0.2 to 4 metres.

Examples: pondweeds, water milfoils, coontail, Canada waterweed

3. Floating Leaved - These plants are rooted in the hydrosoil, have large, broad floating leaves on long leaf stalks and flowers extending above the surface. They are perennials with stout rhizomes or creeping root stalks.

   Examples: water lily, water smartweed

4. Emergent - These are rooted in the hydrosoil or on exposed soil where the water table is within 0.5 metres of the soil surface. Leaves and flowers extend above the water surface on rigid stems.

   Examples: cattail, bulrushes

These categories for aquatic plants can be used as an initial step to identification. The distinctions between each category are broad and some species can be placed in more than one category as they may have a different structure under a different environmental condition. For example, water smartweed may also be seen in an emergent form on shoreline areas. These categories are useful however, as a starting point to identification.

References that are useful for aquatic plant identification:

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STUDY QUESTIONS

1. What are the three types of algae?
2. What type of algae looks similar to an aquatic macrophyte?
3. What are the four types of aquatic macrophytes?

V. MANAGEMENT OF AQUATIC PLANTS

When aquatic plant growth causes problems, there are management or control measures that can be taken. The short term goal of aquatic plant management is to simply reduce or eliminate the existing stand. In the long term, however, the objective of aquatic plant management is to maintain the growth of aquatic plants at an acceptable level - one that is environmentally sound and aesthetically pleasing, and one that permits efficient use of water.

Overabundant aquatic plant growth is a symptom of a disorder or imbalance in the aquatic environment. This imbalance may be an excess of nutrients as is often the case, or a lack of competing species and predators. Aquatic plant problems cannot be solved by a single, one shot treatment of existing plants. Aquatic plant management is a long term task that requires treatment of symptoms (plant growth) as well as causes. A cure is attained when ecological balance is restored and maintained.

When planning for aquatic plant control, the prime consideration is what the water is used for. A control method that may be appropriate in a lake used for recreation may not be appropriate for an irrigation reservoir or canal. What may be suitable in a cooling pond may not be suitable in a farm dugout. A drainage ditch may require near total removal of vegetation whereas in a lake used for fishing, a certain amount of vegetation is required for fish habitat.

One must be aware of secondary consequences that could occur following implementation of a control measure. Occasionally, removal of one type of vegetation favors the growth of another.

Algae blooms could occur due to release of nutrients when submersed macrophytes are killed. Growth of submersed macrophytes may be stimulated by increased light levels when surface covering plants or planktonic algae are removed. Erosion of shoreline soils is a problem when all vegetation is removed. Fish mortality could occur due to suffocation as decaying plants use up dissolved oxygen in the water.

An ideal aquatic plant management program would provide long term solutions and avoid undesirable side effects resulting from control measures.

Aquatic plant management techniques involve a number of different principles each showing a particular advantage to a particular set of circumstances. No single technique is a total remedy in itself. The aquatic plant manager must choose techniques or combinations of techniques that would be most appropriate to each aquatic weed problem.

Aquatic plant management techniques can be grouped into five categories:

- prevention
- habitat manipulation
- mechanical
- biological
- chemical.

A. PREVENTION

As aquatic weed growth gets more and more severe, the cost of control becomes greater in proportion. It also becomes increasingly difficult to restore the affected water body to a useful state. Prevention of aquatic weed problems is desirable from an economic, operational, and environmental standpoint.

Before an aquatic weed problem occurs, preventative measures should be implemented by incorporation into design, construction, and/or maintenance. Preventative measures can also be used after an aquatic plant control program is undertaken.

Some preventative approaches to aquatic plant management:

1. Channel Design and Construction
   - Use artificial channel linings when feasible, to provide a physical barrier to rooting and growth.
   - Construct channels deep and narrow with steep banks to limit light and suppress growth of rooted species.
   - Use as steep a grade as possible to allow swift flow rates and prevent deposition of silt, seeds, and fragments.
   - Avoid having pockets of standing water when channels are dewatered. Standing water left over winter will allow overwintering structures to survive and grow next spring.
   - Seed ditchbanks to suitable low growing grasses to prevent soil erosion and silt deposition downstream.
   - Design channels for carrying capacities greater than maximum projected flows. This will prevent bank overflow due to aquatic plant growth. It is important to remember however, that slow currents and shallow water are favourable to aquatic plant growth and should be avoided.

2. Pond or Dugout Design and Construction

- Construct steeply sloping banks that are seeded, gravelled, or otherwise protected from soil erosion.
- Clear the basin of topsoil and organic debris before filling.
- Prevent silt laden and nutrient rich runoff waters from directly entering ponds.
- If possible allow for control structures to facilitate raising or lowering water level. Water level fluctuation can be effective against some aquatic plant species.
- Prevent general access to ponds by livestock.

3. Maintenance

- Conduct surveillance to detect aquatic plant infestations in their early stages so that control measures can be implemented at a minimal cost.
- Remove trash, weed fragments, and other debris from the water.
- Prevent deposition of aquatic weed fragments carried from other areas on boating equipment.
- If facilities permit, fluctuate water levels periodically to desiccate submersed species and drown shoreline weeds.

B. HABITAT MANIPULATION

Habitat manipulation is a management technique aimed at altering one or more environmental conditions so as to make it unfavorable to plant growth. Future growth is minimized as long as the altered state is maintained.

Environmental conditions that are optimal for one species of aquatic plant may not be optimal for another. Use of a single technique may work for one species or group of species but may not work for another. It may be necessary to vary or combine techniques in order to improve overall effectiveness.

Some habitat manipulation techniques that have been used for aquatic plant management are:

1. Light Limitation
    - a. Water soluble dyes
        - absorb light, reducing penetration through the water column, thereby suppressing plant growth
        - use is limited to confined water bodies with little or no input of fresh water
        - not effective in water less than 1 metre deep
    - b. Dredging
        - deepens water body beyond point at which sufficient light reaches the bottom
        - limited to small areas due to expense and spoils disposal
        - dredging depth depends on water color and clarity. It should be understood that dredging too shallow has no effect and dredging too deep, though effective, is unnecessarily costly.
    - c. Floating Shades (black polyethylene sheets)
        - blocks out light at the surface
        - effective and can be removed after plants have died out
        - limited to small areas, prevents use of water surface while installed and must be anchored well

d. Bottom Barriers

- sheets of polyethylene, fibreglass or fabric laid over the bottom
- limit light and also provide a physical barrier to growth
- use restricted to small areas
- duration of control depends on duration of installation and siltation rates

e. Shading Vegetation on Banks

- reduces weed growth near shorelines

2. Water Temperature Reduction

a. Replacing Warm Water With Cold Water

- practical, if at all, only in small water bodies

b. Shading

- planting shading vegetation on banks reduces daytime water heating and also limits light

3. Nutrient Limitation

a. Aluminum, Iron, Calcium Compounds

- precipitate phosphorous from the water column
- success has been reported when aluminum and calcium are used in combination with aeration
- nutrient inputs must be controlled, however, nutrients in hydrosoil are still available for uptake by rooted plants
- most effective on planktonic algae
- limited to small water bodies

4. Water Level Fluctuation

- lowering of water levels over winter exposes submersed aquatic plants to desiccation and freezing

- raising water levels may drown some emergent species
- limited to water bodies with control structures
- temporary drawdown does not control all species

5. Bottom Substrate Alteration

   a. Dredging

      - removes nutrient rich sediments
      - limited to small areas
      - drastically changes aquatic environment

   b. Addition of Clean Sand or Gravel

      - a poor rooting medium lacking nutrients for growth
      - limited to small areas
      - control may be temporary and procedure cannot be repeated indefinitely

It is important to remember that any habitat alteration along or in public waters requires approval from the appropriate government agency.

C. MECHANICAL CONTROL

The objective of mechanical control is to remove vegetation from its habitat by manual or mechanical methods.

Unless root systems are removed, mechanical control methods are short term in effect, that is, more than one treatment is required per season. All mechanical methods exhibit one significant advantage - results are promptly apparent, thus the water body can be used immediately after treatment. To their disadvantage, mechanical control methods are often labour intensive, slow, and some machines may be costly to purchase, operate, and maintain.

It is imperative that, following mechanical control operations, aquatic plant debris be removed from the water. This is to prevent regrowth from fragments, to avoid reintroduction of nutrients from plant pieces as they decay, and to prevent clogging of downstream structures and intakes.

Mechanical control techniques include:

1. Hand Pulling or Cutting
   - practical for light infestations of submersed aquatic plants in shallow waters, such as around boat docks or small swimming areas
   - plants may be pulled by hand, rake or hook, or may be cut-off by sweeping a thin fibreglass or metal rod along the bottom
   - severed or pulled plant pieces will float to the surface where they should be removed and disposed of on shore
   - these procedures may have to be repeated during the season unless roots are removed as well
2. Dragging
   - could include towing a gang of hooks behind a boat or dragging a heavy chain down a ditch between two tractors
3. Cutting
   - aquatic plant cutters for submersed weeds are available commercially or can be constructed from plans. They consist of a cutting bar mounted on a floating self-propelled platform.
   - depth of cutting depends on the reach of the cutting bar
   - emergent plants should be cut below water level for longer lasting control

- time of cutting of perennials should correspond to when food reserves in root systems are low (during early stages of flowering)
- emergent plants i.e. cattails can be eventually controlled by 2-3 cuttings per season

4. Harvesting

- aquatic plant harvestors utilize a cutting system coupled with a mechanism to remove fragments from the water

5. Rotovating

- involves tilling the hydrosoil to dislodge aquatic plants which float to the surface where they can be removed
- rotovating hydrosoil following drawdown exposes roots and rhizomes to freezing and desiccation

6. Suction

- operates on the principal of a large vacuum cleaner
- aquatic plants and sediment are sucked up from the bottom

D. BIOLOGICAL CONTROL

Biological control of aquatic plants involves the introduction of native or foreign predators, disease organisms or parasites to the aquatic system. Examples include grass carp (weed eating fish), midge larvae, weevils or snails. When a foreign organism is introduced to any ecosystem there is a chance that the organism could develop into a more serious pest than the original. This is a particular danger in aquatic systems because water bodies are often not completely closed off from each other.

Extreme care must be taken in the use of biological agents for aquatic weed control. One must be able to predict what will happen to the foreign organism once it is introduced to the system. For these reasons biological control of aquatic vegetation is not yet a technique that can be put into general use. More research is required into biological control before this can happen.

STUDY QUESTIONS

1. Name four categories of aquatic weed control techniques.
2. What form of aquatic weed control is not yet practical for general use?
3. What form of aquatic weed control changes environmental conditions that are favourable to aquatic plant growth?
4. What is the main advantage of mechanical aquatic weed control?
5. How can banks be constructed to prevent the growth of aquatic plants?

VI. MANAGEMENT OF AQUATIC PLANTS WITH HERBICIDES

A. FEDERAL PESTICIDE REGULATIONS - THE PEST CONTROL PRODUCTS ACT

The Pest Control Products (P.C.P.) Act is the main law governing pesticides in Canada. This act requires that all products used for the control of pests (weeds, insects, rodents, etc.) be REGISTERED, have proper LABELLING, and have a CLASS DESIGNATION.

1. Registration

Before a pesticide product is registered in Canada, its manufacturer must demonstrate that it is effective in its intended use, and that its intended use will present no environmental or human health problems. Registration of a pesticide is the end result of years of testing and expense. It ensures that, under proper use conditions, the product will be safe and effective. Every pesticide that is registered in Canada has a Pest Control Products (P.C.P.) number printed on its label.

2. Labelling

The pesticide product label is the result of the registration process. The label tells the applicator what the product is effective for, how it must be used, where it can be used, and what precautions should be taken when using it.

3. Class Designation

Pesticides may only be used for the purposes registered under the Pest Control Products Act. The Federal Government has designated 3 classes of pesticides.

a. Restricted Class - These products can be dangerous if not used with knowledge and care. Restrictions can be with respect to:

   - the way the compound must be stored
   - who may apply or use the chemicals
   - where the chemical can be applied.

   Herbicides registered for aquatic weed control in public waters are included in this class.

b. Commercial, Agricultural, or Industrial Class - These products have a low to medium toxicity and some environmental risk is associated with their use unless they are handled properly.

c. Domestic Class - These products have low toxicity with no significant persistence in the environment. These products are the only class of products that can be used in or around the home by the householder.

B. PROVINCIAL PESTICIDE REGULATIONS - THE AGRICULTURAL CHEMICALS ACT

The Agricultural Chemicals Act controls and regulates the application, handling, sales, transport, and storage of pesticides in Alberta.

1. Licencing

Licences are required by persons who operate a business or provide a service involving the use or application of pesticides or who for hire or reward, apply or offer to apply pesticides. Licences are classified according to type of pesticide application:

Class A - agriculture (general)

Class B - government employees

Class C - seed treatment

Class D - right-of-way vegetation control

Class E - aerial

Class F - structural

Class G - landscaping and parks

Class H - aquatic vegetation control

Class J - greenhouse

Class K - stored grain

Class L - biting fly

Class M - other

To become a licenced pesticide applicator, a person must fulfill the following requirements:

- be 18 years of age or older
- have related experience in pesticide application (one season on the job)
- possess adequate knowledge concerning the proper and safe use of the pesticides used in the class of licence applied for (preferably by taking a certified training course)
- pass a provincial examination concerning the above requirement
- be medically fit (requires a medical examination signed by the examining physician) to use pesticides
- possess adequate insurance (minimum $250,000 public liability and $50,000 property damage)

Licences are valid for 3 years following the individual's birthday.

The Minister of Environment for Alberta can suspend, cancel, or place restrictions on any licence.

The licenced pesticide applicator must keep records of pesticide applications. Records must be retained for at least 3 years and must be made available upon the request of an inspector.

Persons who, for lack of some qualification (such as experience or training), cannot qualify for a full pesticide applicator licence, may obtain an INTERIM LICENCE. Interim licences are valid for one year and cannot be renewed. The person having an interim licence must obtain the lacking qualification during the season following the issuance of the licence. Interim licence holders can apply pesticides but must be supervised by a fully licenced applicator.

Pesticide applicator licences are obtained by making application to Alberta Environment, Pollution Control Division, Pesticide Chemicals Branch.

2. Permits

A PERMIT must be obtained from Alberta Environment for the following pesticide applications:

a. Pesticide applications made to or over an OPEN BODY OF WATER and pesticide applications made on land within 30 horizontal metres of an OPEN BODY OF WATER. - An open body of water is defined as the bed and shore of any river, stream, watercourse, irrigation canal, drainage canal, lake or slough, whether it contains water continuously or intermittently. Municipal reservoirs, and reservoirs and dugouts on private land, are NOT considered open bodies of water. Lakes or sloughs are NOT considered open bodies of water IF they are less than 4.2 hectares in size, completely surrounded by private land, and have no drainage of water from them through the private land.

NOTE: Open bodies of water cannot be used to fill spray tanks unless intake lines are equipped with a device to prevent back flow.

b. Pesticide applications made on utility or transportation corridors or on other public land for vegetation control in the GREEN AREA of the province. The GREEN AREA includes provincial forestry reserves.

c. Applying pesticides that are not registered for the intended uses.

d. Applying pesticides listed in Schedules A or B of the Alberta Pesticide Sales, Use and Handling Regulation (Alberta Regulation 213/80).

3. Pesticide Storage (warehouses, distribution centres or stores)

a. ALL PESTICIDES must be stored in a clean, orderly area marked with warning signs. Pesticide storage areas must be locked and be equipped with exhaust fans.

b. Schedule A, B, and C pesticides (Alberta Regulation 213/80) must be stored in an area exclusively for pesticides. Emergency telephone numbers must be posted and safety equipment must be readily accessible. The storage area must conform to fire resistant standards. No drain must lead out of the storage area.

4. Pesticide Transportation and Disposal

a. No one can transport pesticides, materials mixed with pesticides or pesticide containers unless the pesticide material is kept separate from plants and any food item for either animals or humans.

b. Anyone transporting a pesticide in bulk must affix a label in a conspicuous place indicating:

- product or chemical name
- concentration
- name of manufacturer or owner of the pesticide

c. Pesticides, any material that has been treated with a pesticide, or pesticide containers, can only be disposed of in a manner approved by the Minister of the Environment.

C. PESTICIDE HANDLING, STORAGE, AND DISPOSAL

1. Pesticide Hazards

Pesticides are chemicals designed to kill living organisms (insects, weeds, microbes, rodents, etc.) and therefore they must be handled as poisons. The toxicity of a pesticide is usually expressed in terms of its LD_{50} value. The LD_{50} refers to the amount of a pesticide's active ingredient that will kill 50% of a population of test animals. The LD_{50} is usually determined from an oral dose administered to laboratory rats. As such, LD_{50} values are used for comparative purposes to show differences in toxicities between pesticides. The lower an LD_{50} value is, the more toxic is the chemical. However, because the LD_{50} refers to a pesticide's active ingredient and not to the formulated pesticide as it comes from the distributor, it does not necessarily reflect the hazard presented by the chemical.

For example, the toxicity of the herbicide diquat is 230 mg/kg. This means that 50 out of 100 rats will be killed if each one is given 230 mg of diquat for every kilogram of their body weight.

The hazards associated with pesticide use depend not only on their toxicity, but on the way they are handled, stored, and disposed of. Pesticides that have been rigorously tested through the lengthy process of product registration present little hazard _IF_ they are used properly and according to label directions.

Pesticide poisoning can be of two types: acute or chronic. Acute poisoning results when someone is exposed to a large amount of a chemical over a short period of time. This type of poisoning is usually associated with sudden, accidental pesticide exposure. Chronic poisoning results from small but repeated exposures to a chemical over a longer period. This type of poisoning is usually associated with careless pesticide handling.

2. Handling and Mixing Pesticides

Of the various work activities associated with pesticide use, the mixing and loading operation is considered the most hazardous to the applicator. This is because any spills or splashes will generally contain concentrated pesticide. The following general safety instructions should be observed during the mixing and loading of pesticides:

- Having selected the right pesticide for the job, read the label and carry out the necessary calculations. Obtain the proper equipment, including protective clothing, and have first aid equipment on hand.
- Never work alone when handling hazardous pesticides.
- Mix chemicals outside or in a well ventilated area.

  Carefully open containers. Never put any part of your body directly over the seal or pouring spout. The release of pressure may cause the liquid to blow out of the container. Open sacks with a knife rather than tearing them because dry formulations can billow up in your face. Always stand upwind when loading or mixing pesticides.

  NOTE: Open bodies of water cannot be used to fill spray tanks unless intake lines are equipped with a device to prevent back flow.
- Have clean measuring and transfer containers available. The measuring containers should be thoroughly cleaned after each use.
- As pesticide containers are emptied and drained, rinse them three times. Drain each rinse into the spray tank before filling to final level (this also simplifies container disposal). Puncture used containers to prevent re-use.
- Cleanup spills immediately. If pesticide is spilled on the skin, wash it off with soap and water. Contaminated clothing should be changed as soon as possible and washed before using again.
- Protective gloves should be washed before removing them.

- Persons mixing, handling, or applying pesticides should never smoke, eat, or drink until they have washed thoroughly.

There are times when the chance of overexposure are increased and the applicator has to be extra careful:

- New personnel - new and inexperienced people may be handling chemicals for the first time. Overexposures are more likely to occur among these people until they gain some training and experience.
- A long hot spell in summer - many people become tired of using uncomfortable protective clothing and respirators during hot weather. Also people are more likely to become dehydrated during hot weather and may be more susceptible to some chemicals.
- Long periods of work - when the work period has been prolonged, small repeated exposures may bring an applicator to the point where an additional small exposure may result in poisoning.

3. How to Treat Contaminated Clothing

The clothing you wear when you apply chemical pesticides may pick up residues which can enter your body through the skin. The pesticide does not have to be spilled on the clothing - contamination may be caused by spray drift, or by walking through recently sprayed vegetation.

Removing the contamination using home laundry procedures works well, but some extra care is required.

Firstly, contaminated work clothes should be laundered daily and separately from other laundry.

Use hot water (80°C), a full water level and the recommended amount of heavy duty detergent.

Remove any leftover chemicals from the washing machine by running the machine through the complete cycle adding detergent but no clothing.

4. Pesticide Storage

The first thing that should be noted is that pesticides are poisons and have to be stored as such. Never store pesticides in the home: to do so is just asking for trouble!

Pesticides should always be stored well away from food or feed. Herbicides of all types need to be stored separately from other pesticides. This is to prevent possible cross contamination and errors in mixing.

Containers should be placed on racks or shelves to enable any label or container deterioration to be noted at an early date.

It is a good idea to keep an inventory of all your pesticide materials. When purchasing new pesticides, mark the date of purchase on the container to keep track of outdated pesticides.

Certain safety and other equipment should always be available in the storage area:

Washing facilities, soap and towels.
Fire extinguishers, sand buckets, etc.
Sawdust, sand or earth to absorb leakage.
Suitable empty containers, shovels, brooms, etc.

Protective clothing, overalls, rubber or neoprene gloves/boots/apron and face shield; also suitable respiratory protective equipment if highly toxic compounds are stored.

5. Pesticide Spills

Any spillage from leaking packages should be cleaned up immediately. Properly dispose of any leaking or damaged containers. When pesticides are being stored for any length of time, examine containers regularly to be certain that no leaks have occured.

If a spill does occur, you should isolate the affected area and keep all unauthorized persons away. It is important that appropriate protective clothing is worn by all personnel who are dealing with the spill. The building should be ventilated before and while the cleanup procedures are being carried out.

If the spill is a liquid, use activated charcoal, absorptive clay, vermiculite, pet litter, or sawdust to absorb the spill. Use enough to soak up most of the liquid and then sweep or shovel it into a large drum. If the spill is on earth or gravel, the contaminated area should be dug up and disposed of. When using water to wash up pesticide spillage do not permit this water to enter the sanitary sewer or storm sewer.

Cover contaminated areas with lime or bleach to neutralize the pesticide and rinse the areas with plenty of water to wash away any remaining poisons.

Once the spill has been cleaned up you should check your storage area carefully to see if any other pesticides were contaminated by the spill. If they were, don't take a chance on using them - dispose of them.

If a spill occurs near a lake, stream or irrigation canal, immediately take steps to confine the material by blocking off all possible escape routes. If some material escapes into the water, ensure that all downstream water users are notified to cease using the water until it is deemed safe. Notify Alberta Environment, Pollution Control Division (1-800-222-6514) to report major spills and to obtain advice on hazards and cleanup procedures.

6. Pesticide Disposal

There are basically two disposal problems: disposal of surplus pesticides and disposal of empty pesticide containers.

Surplus pesticides which are still in unopened containers may be accepted back by the manufacturer. If your pesticide container has been opened but the contents are no longer useful or they are out of date, you may dispose of Schedule A, B, or C* pesticides by calling Alberta Environment. Alberta Environment will then advise you as to disposal procedures or they may collect the pesticide and dispose of it for you. Schedule D & E* pesticides may be disposed of at Regional Landfills. Be sure to call the landfill to get approval before you dispose of the pesticide. Disposal will usually entail pouring the pesticide over a patch of soil and then neutralizing the soil by covering it with lime or some other substance. Your Regional Landfill director should be able to advise you about disposal procedures.

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* Pesticide schedules are described in Alberta Pesticide Sales, Use and Handling Regulation (213/80).

Empty containers are to be disposed of at pesticide container disposal sites after each container has been triple-rinsed to remove most residues and then punctured to prevent further use of the container. Check with the local Agricultural Fieldman for location of pesticide container disposal sites in your area.

7. Fires Involving Pesticides

Fires in which pesticides are involved present a much greater hazard than a normal fire. When pesticides burn, toxic vapors are given off which pose a hazard not only to fire fighters but to individuals and property located downwind from the fire. The best method for dealing with fire is to prevent its occurance.

Your local fire department can assist you in designing a fire prevention plan and inspect your facilities for fire hazards. This procedure also makes the fire department aware of what equipment and procedures would be involved should a fire occur. Firemen have a difficult enough job without having to face toxic fumes which they are unaware of and unprepared for.

If a fire does occur where pesticides are located immediately contact the Fire Department and then notify Alberta Environment (1-800-222-6514). All material remaining in the fire area must be considered contaminated and disposed of accordingly. This will involve the disposal of containers, building materials, and the water used in fighting the fire. Proper disposal will require you to obtain special permits from Alberta Environment and the procedures outlined in the permit could prove very costly to carry out. It is therefore advisable to consider putting extra effort into fire prevention.

D. HERBICIDE USE FOR AQUATIC PLANT CONTROL

There are 27 herbicide products - made up from any one of 11 active ingredients - registered in Canada for use as aquatic weed control agents. Each herbicidal active ingredient has properties which allow it to be effective against one group of aquatic plants, but not others. Furthermore, each herbicide has properties which allow it to be used safely in some circumstances, but not in others.

Herbicides must be applied correctly and in the proper dosages in order to be safe and effective. An applicator must be able to make informed decisions when undertaking an aquatic weed control program. This involves a knowledge of the aquatic weed problem being faced, the physical aspects of the water body to be treated, the uses of the water to be treated, the herbicides available for the intended purpose and their properties, and the proper application procedures.

Know the Problem - this enables one to choose what, when, where, and how to apply.

- Identify the problem weeds and what stages of growth they're in.
- Learn about their habits - how they reproduce and overwinter, where they grow best, how fast they grow.

- Determine the density and size of the infestation.

Know the Situation of the Problem - this enables one to choose whether or not chemical control should be used. If chemical control is appropriate, this will influence what, when, where, and how to apply.

- Determine the use(s) for the water - whether it is used for irrigation, human or animal consumption, recreation, or for habitat and production of fish and wildlife.
- Find out if the water uses can be disrupted and for how long. Water use restrictions may be implicit in the use of some herbicides.
- Determine if there is outflow from the area to be treated - if so, determine where it goes, what it is used for, and if it can be regulated and for how long.
- Determine the volume or flow rate of the water to be treated.
- Determine the chemical and physical characteristics of the water. Depending on the chemical used, this could include water temperature, turbidity, pH and hardness.

Choose the Appropriate Herbicide - this will depend on the above factors.

- Find out which herbicides are registered and approved for the intended purpose.
- Rate the herbicides according to effectiveness, desired selectivity, safety to the user, toxicity to users of the water (humans, fish, wildlife), and possible effects on desirable vegetation.
- Determine persistence of the herbicide following application.

- Consider relative costs between products.

Obtain the Necessary Permits and Approval - Alberta Legislation requires that government approval be obtained (permits) for application of any pesticide (including herbicides) to open bodies of water (see page 28). Permits are applied for by submitting a completed application form to Alberta Environment, Pesticide Chemicals Branch. Regional branch offices can be contacted for further information.

- Inform persons (downstream water users, neighbors, etc.) that may be affected by the intended application.

Make the Application

- Calculate the correct dosage and calibrate application equipment.
- Wear appropriate safety equipment when mixing and applying the herbicide.
- FOLLOW THE HERBICIDE LABEL TO THE LETTER.

Determine the Cause of the Weed Problem - long term control is best achieved if the cause of the problem is identified and corrected.

1. HERBICIDES REGISTERED FOR AQUATIC PLANT CONTROL IN CANADA

ACTIVE INGREDIENTS Products	WHERE APPLIED	SITE OF APPLICATION	WEEDS
ACROLEIN 1. Magnacide H[a]	flowing water	irrigation canals	submersed aquatic weeds, filamentous algae
AMITROLE 1. Amino Triazole[b] 2. Cytrol Amitrole-T[b]	plant foliage	marshes, drainage ditches	cattail
3. Amitrole-T[c]	plant foliage	water bodies wholly confined to users property	cattail
COPPER 1. Swimtrine[d] 2. Black Algaetrine[d]	non potable water	swimming pools	algae
3. Algimycin PLL-C[e] (liquid or slow release tablets)	non potable water	farm, fire, and fish ponds wholly confined within users property	-algae (all categories) -solid forms especially effective on macrophytic algae (*Chara sp*)
4. Cutrine Plus[d] Algaecide (liquid or granular)	as above	as above, include fish hatcheries	as above

ACTIVE INGREDIENTS Products	WHERE APPLIED	SITE OF APPLICATION	WEEDS
DALAPON 1. Dowpon[f] 2. Dowpon M[f]	plant foliage	drainage ditches	-cattail, phragmites, emerged grasses
3. Basfapon[g]	plant foliage	drainage ditches, irrigation ditches	-cattail, phragmites, emerged grasses
DIQUAT 1. Reglone-A[h] 2. Norkem 500[i]	still or slow flowing water	lakes, canals, farm ponds, farm dugouts and farm ditches	-submersed aquatic weeds -free floating aquatic weeds
3. Cantol 450[j]	still or slow flowing water	water bodies wholly confined to users property	-submersed aquatic weeds, -free floating aquatic weeds
DIURON 1. Karmex[k]	soil	irrigation ditches, drainage ditches	-rooted vegetation
	water	ponds and dugouts with little or no flow through	-algae (all categories) -submersed and free floating aquatic weeds
2. Marzone[l] Weedkiller 3. Diurex 80W[m,n]	soil	irrigation and drainage ditches	-rooted vegetation

ACTIVE INGREDIENTS Products	WHERE APPLIED	SITE OF APPLICATION	WEEDS
FENAC			
1. Fenatrol Liquid Herbicide[o]	soil	lakes, reservoirs, farm ponds, irrigation ditches, drainage ditches	submersed aquatic weeds
	still water	lakes, ponds with little or no water exchange	submersed aquatic weeds
GLYPHOSATE			
1. Roundup[p]	plant foliage	non cropland, dry drainage ditches	cattail
PARAQUAT			
1. Gramoxone[h] with wetting agent	plant foliage	ditches, ponds, dugouts, lakes and canals	cattail, bulrushes emerged grasses
2. Gramoxone S[h]	plant foliage	ditches, ponds, dugouts, lakes, and canals	cattail, bulrushes, emerged grasses
	still or slow moving water (when mixed 1:1 with Reglone A)	ditches, ponds, dugouts, lakes, and canals	submersed and free floating aquatic weeds
SIMAZINE			
1. Princep 80W[q] 2. Simmaprim 80W[q] 3. Princep Nine-T[q] 4. Simadex Simazine[r] 80W	water	ponds with little or no water exchange	filamentous and macrophytic algae, submersed and free floating aquatic weeds
5. Simadex Simazine[r] Flowable	soil	drainage ditches, canals, ponds	submersed and emergent aquatic weeds

ACTIVE INGREDIENTS Products	WHERE APPLIED	SITE OF APPLICATION	WEEDS
2,4-D			
1. Aqua-Kleen[o] Granular	still or slow flowing water	ponds, lakes, reservoirs, drainage ditches, canals, rivers, streams, and marshes	water milfoil, bladderwort, water lily, coontail
MIXTURE ATRAZINE MONURON SIMAZINE			
1. Algimycin GLB-X[e] Algaecide	water	small ornamental ponds	Algae (all categories)

[a] Magna Corporation
[b] Cyanamid Canada Inc.
[c] Allied Chemical Services Ltd.
[d] Applied Biochemists Inc.
[e] Great Lakes Biochemists Co Inc.
[f] Dow Chemical of Canada Ltd.
[g] BASF Canada Inc.
[h] Chipman Chemicals Ltd.
[i] Kem Manufacturing Canada
[j] Cantol Ltd.
[k] DuPont of Canada Ltd.
[l] Marzone Chemicals Ltd.
[m] Solcoor Canada Ltd.
[n] Uniroyal Chemical
[o] Union Carbide Agricultural Products
[p] Monsanto Canada Inc.
[q] Ciba-Geigy Canada Ltd.
[r] FBC Chemicals Canada Inc.

2. HERBICIDES APPLIED TO WATER OR HYDROSOIL - WATER USE RESTRICTIONS AND HAZARDS TO FISH

HERBICIDE	MINIMUM TIME RESTRICTIONS ON USE OF TREATED WATER	FISH HAZARD
ACROLEIN	Consumption - humans or dairy cattle - 48 hours Swimming - 48 hours	directly toxic to fish at normal use rates
COPPER	Consumption - not for use in potable water	- very toxic to fish in soft water - may otherwise be toxic to fish at concentrations above 0.4 ppm (copper) - fish hazard from oxygen depletion due to decay of treated vegetation
DIQUAT	Consumption - human or animal - 24 hours Swimming - 24 hours Irrigation - 5 days	- fish hazard from oxygen depletion due to decay of treated vegetation
DIURON	Consumption - not for use in potable water Irrigation - ponds - within one year of treatment. Ditches - flush for 3 days and waste the flush water	ponds - fish hazard from oxygen depletion due to decay of treated vegetation
FENAC	Consumption - water treatments (human or livestock) - spring following treatment Irrigation - water treatments - spring following treatment. - soil treatments - flush for 24 hours and waste the flush water	water treatments - fish hazard from oxygen depletion due to decay of treated vegetation

HERBICIDE	MINIMUM TIME RESTRICTIONS ON USE OF TREATED WATER	FISH HAZARD
PARAQUAT	Consumption - human or animal - 7 days Swimming - 7 days Irrigation - 5 days	- fish hazard from oxygen depletion due to decay of treated vegetation
SIMAZINE	Consumption - not for use in potable water Irrigation - do not use water from treated ponds for irrigation Fishing - fish taken from treated ponds should not be used for human consumption	- ponds - fish hazard from oxygen depletion due to decay of treated vegetation
2,4-D	Consumption - human or animal - 60 days Irrigation - 2,4-D sensitive crops - 60 days	- fish hazard from oxygen depletion due to decay of treated vegetation

3. FISHERIES PROTECTION

Aquatic herbicides with the exception of copper and acrolein are not directly toxic to fish at normal use rates. Fish can be affected however by secondary occurrences due to aquatic weed control activities.

Two things happen when aquatic plants are killed. First, because photosynthetic processes cease, an important source of oxygen to the water no longer exists. Second, the dead plants quickly begin to decay, using up what oxygen is present in the water. The result is fish mortality due to suffocation, if the quantity of decaying vegetation is large enough.

Another effect results from the removal of fish habitat. Fish use aquatic vegetation directly for cover and indirectly for food and reproduction. They cannot survive without aquatic plants.

Here are some measures that can be taken to avoid adversely affecting fish populations while undertaking aquatic weed control.

- Begin applications at shoreline and work outwards to avoid trapping fish in shallow water.
- Treat large areas in strips; do 1/2 of the total area at one time, the remainder 2-3 weeks later.
- Do not apply more than the recommended rate of application. Apply evenly over the area to be treated to avoid pockets of high concentration.
- Identify important fish spawning or habitat areas and avoid treating these.
- Treat early in the season before weeds become dense. This will lessen oxygen problems.
- If oxygen depletion cannot be avoided, aerate the water immediately following application and for about one week.
- When fish are of concern in a farm pond, be very careful when using copper compounds. Copper compounds are toxic to fish particularly in soft water.

4. HOW AQUATIC PLANT CONTROL HERBICIDES WORK

HERBICIDE	MODE OF ACTION
ACROLEIN	kills only what it contacts; destroys cells
AMITROLE	absorbed slowly by foliage; translocated throughout the plant; inhibits chlorophyll formation and regrowth from buds
COPPER	absorbed well by algae, poorly by foliage of other plants; translocated throughout the plant; affects enzyme systems
DALAPON	absorbed by roots and foliage; translocated throughout the plant accumulating in young tissue; disrupts metabolic processes
DIQUAT	absorbed by foliage; poorly translocated thus action is contact in nature (kills only what it contacts); affects respiration and photosynthesis
DIURON	absorbed well by roots, poorly by foliage; translocated upwards through system; acts as an inhibitor of photosynthesis

HERBICIDE	MODE OF ACTION
FENAC	primarily absorbed by roots; translocated
GLYPHOSATE	absorbed by foliage; translocated throughout the plant
PARAQUAT	similar to diquat
SIMAZINE	absorbed well by roots; poorly by foliage; translocated upwards, accumulates on leaves and growing points; main action is as a photosynthesis inhibitor
2,4-D	absorbed by roots and foliage; translocated throughout the plant accumulating at growing points; causes abnormal growth response

5. APPLICATION EQUIPMENT AND TECHNIQUES

Treatment of water bodies such as lakes or ponds requires the use of a boat or other floating craft. Craft can be fitted with conventional or homemade application equipment - pumps, tanks, booms, hoses, etc. - provided that the weight of this equipment (wet or dry) plus operators does not exceed the craft's capacity.

A distribution boom fitted with trailing weighted hoses at the nozzle points can be used for injecting liquid sprays beneath the water surface. Replace hoses with nozzles for surface application.

Two clean oil drums mounted on their sides with a weighted hose trailing from the drum opening, serve to deliver liquids beneath the water surface by gravity. Filler spouts must be attached and a device for measuring fluid levels in the drums is needed. Make dry runs, using water, to determine how quickly the tanks will empty (output) at expected speeds of application.

Smaller areas can be treated by injecting a regulated flow of herbicide solution through a hose into the slipstream of an outboard motor. Alternatively, a boat bailer can be mounted on the cavitation plate of an outboard with a hose running into the spray tank. The chemical is drawn out by suction into the prop wash. With both these methods, the action of the outboard helps to disperse the chemical through the water.

A word of caution about the use of outboard motors for chemical application. Some herbicides - notably diquat - are completely inactivated when they come into contact with soil. Use of outboards in shallow enough water will stir up the bottom causing the hydrosoil to become suspended in water. The suspended sediment will render the chemical ineffective. Treat shallow areas from shore or from a rowboat using a spray gun or backpack sprayer for surface application. NEVER stir up the bottom when applying diquat, diquat/paraquat, diuron, simazine, or copper solutions to water.

Granular formulations can be applied with rotary seeders to provide even distribution. Rotary seeders can be power or hand driven. Hand driver seeders are appropriate for small areas.

Correct distribution of herbicide over the treatment area is imperative. Know how much chemical is being delivered by your equipment, keep you speed constant, shut off delivery when turning about and know how wide a swath the chemical makes in one pass. Use reference points such as buoys or markers on shore so that you know what areas have been covered. Mark, with buoys, deeper areas that may require more chemical.

Emergent aquatic plants can be treated by using a power spray gun or backpack sprayer. Plant foliage must be thoroughly wetted with the prescribed spray solution. The effectiveness of amitrole and dalapon may be improved if a wetting agent (spreader-sticker) is added to the spray solution. Wetting agents are available commercially. Be sure to refer to the label of the product to be used to find out what wetting agents are compatible with these products. When spraying emergent plants, try to keep sprays on the foliage. Avoid hitting the water.

When using wettable powder formulations it is necessary that the spray solution be kept agitated so that screens, hoses, and fittings do not get clogged. Check periodically to make sure sprayer components are operating efficiently.

6. TIMING THE APPLICATION OF AQUATIC PLANT CONTROL HERBICIDES

The timing of a herbicide application is critical to the success of any weed control operation. Timing will vary with the herbicide used and the type of plant being treated. With the exception of soil active residual herbicides, all treatments should be made before seeds are formed.

HERBICIDE	TARGET VEGETATION	TIMING OF APPLICATION
ACROLEIN	submersed aquatic plants	when plants are small - under 30 cm long
AMITROLE	cattail	during early flowering
COPPER	planktonic algae filamentous algae *Chara*	- when algae growth first becomes visible and water temperature is above 15°C - on bright sunny days
DALAPON	cattail	from early flowering to maturity, until 7 days before anticipated killing frost
DIQUAT	submersed aquatic plants	- when plants are actively growing but before growth becomes dense - when water temperatures reach 18°C or above - at dawn, dusk, or on overcast day

HERBICIDE	TARGET VEGETATION	TIMING OF APPLICATION
DIURON	weeds and grasses in irrigation and drainage ditches submersed aquatic plants and algae in ponds	- preferably fall, after ditches are drawn down but before ground is frozen - early in the season when plants are actively growing but before growth becomes dense
FENAC	submersed aquatic plants non-flowing water treatment drawdown treatment	- early in the season when plants growth is first observed - as soon as soil is exposed; keep soil exposed for a minimum of 3 weeks following treatment; in areas of low rainfall, apply in fall before soil is frozen to allow chemical to be fixed in soil by winter and spring moisture
GLYPHOSATE	cattail	- from early flowering to maturity, until killing frost
PARAQUAT	submersed aquatic plants emergent plants	- as diquat - when cattails and bulrushes are flowering and to grasses whenever necessary

HERBICIDE	TARGET VEGETATION	TIMING OF APPLICATION
SIMAZINE	submersed aquatic plants, and filamentous algae - non-flowing water treatment	- early in the season when plants are actively growing but before growth becomes dense
	rooted aquatic plants (submersed and emergent) - drawdown treatment	- in fall before soil is frozen or as early in spring as conditions permit
2,4-D	submersed aquatic plants	- early in the season when plants are actively growing but before growth becomes dense

STUDY QUESTIONS

1. What provincial act regulates the use of pesticides?
2. In what areas do you need a permit to apply pesticides?
3. What is an "open body of water"?
4. What is not an open body of water?
5. How can you tell whether or not a herbicide is registered in Canada?
6. What herbicides can be used in lakes for submersed aquatic weed control?
7. What class of provincial licence would a person need to apply herbicides to a lake or irrigation canal?
8. What does one need in order to obtain a pesticide applicator licence in Alberta?
9. How long must water be quarantined from drinking and swimming following an application of diquat?
10. What is the most likely cause of fish mortality following a water treatment with simazine?
11. Will diquat kill the root system of aquatic plants?
12. At what stage of growth should cattails be treated with dalapon?

APPENDIX I

CALCULATIONS USED FOR HERBICIDE APPLICATION

METRICS

All herbicide products now use metric measurements on their labels. Containers are metric size in litres or kilograms and rates of application are given in litres, millilitres, kilograms or grams of product per 100 litres, per hectare, per hectare metre or per cubic metre.

UNITS

The basic units of the metric system are the metre (length), the litre (volume) and the gram (weight). Each of these basic units can be divided into smaller units for the convenience of measuring small distances, volumes or objects, or can be multiplied into larger units for measurement of long distances, large volumes or objects. This is done simply by adding different prefix in front of the words metre, litre or gram.

Six prefixes are commonly used in the metric system:

kilo = 1000

hecto = 100

deca = 10

basic unit = 1 (metre, litre, gram)

deci = $\frac{1}{10}$ (0.1)

centi = $\frac{1}{100}$ (0.01)

milli = $\frac{1}{1000}$ (0.001)

Example: 1 kilometre = 1000 metres

1 kilogram = 1000 grams

1 kilolitre = 1000 litres

1 millimetre = $\frac{1}{1000}$ (0.001) metre

1 milligram = $\frac{1}{1000}$ (0.001) gram

1 millilitre = $\frac{1}{1000}$ (0.001) litre

CONVERSION WITHIN THE METRIC SYSTEM

Converting from one unit to another within the metric system is simply a matter of moving the decimal point either to the right or left. One kilometre which equals 1000 metres also equals 100,000 centimetres, because one metre equals 100 centimetres. Here, decimal is moved two places to the right.

Example: 1 kilogram = 1000 grams = 1,000,000 milligrams

25.78 kilograms = 25,780 grams = 25,780,000 milligrams

WEIGHTS AND MEASURES

Length

Commonly used units - metre (m), kilometre (km), centimetre (cm)

Conversions - 1 km = 1000 m
1 m = 100 cm

Comparison to imperial system - 1 km = 0.62 miles
1 m = 1.1 yards
1 cm = 0.4 inches

Area

Commonly used units - square metre (m^2), hectare (ha)

Conversions - 1 ha = 10,000 m^2

Comparison to imperial system - 1 ha = 2.5 acres
1 m^2 = 10.8 square feet

Volume

Commonly used units - hectare-metre (ha-m), cubic metre (m^3), litre (L), millilitre (mL)

Conversions - 1 ha-m = 10,000 m^3
1 m^3 = 1000 L
1 L = 1000 mL

Comparison to imperial system - 1 ha-m = 8 acre feet
1 m^3 = 220 gallons
1 L = 0.88 quarts
1 mL = 0.035 fluid ounces

Weight

Commonly used units - kilogram (kg), gram (g)

Conversions - 1 kg = 1000 g

Comparison to imperial system - 1 kg = 2.2 pounds
1 g = 0.035 ounces

Interrelation between weight and volume (water)

1 L of water weighs 1 kg

1 mL of water weighs 1 g

D. TABLE OF METRIC TO METRIC CONVERSIONS

When you have ________________ multiply by ________________ to get

****

to get ________________ divide by ________________ when you have

kilometres (km)	1,000	metres (m)
hectares (ha)	10,000	square metres (m^2)
hectare metres (ha-m)	10,000	cubic metres (m^3)
hectare metres	10,000,000	litres (L)
cubic metres	1,000	litres
litres	1,000	millilitres (mL)
kilograms (kg)	1,000	grams (g)
hectare metres (water)	10,000,000	kilograms
cubic metres (water)	1,000	kilograms
litres (water)	1	kilograms
litres (water)	1,000	grams
parts per million (ppm)	10	kilograms/hectare metre

E. TABLE OF IMPERIAL TO METRIC CONVERSIONS

When you have _________________ multiply by _________________ to get

****

to get __________________ divide by __________________ when you have

miles	1.6	kilometre
yards	0.9	metre
feet	0.3	metres
acres	0.4	hectares
square feet	0.09	square metres
acre feet	0.125	hectare metres
gallons	4.5	litres
pints	0.57	litres
fluid ounces	0.03	litres
pounds	0.45	kilograms
ounces	0.03	kilograms
gallons (water)	4.5	kilograms
cubic feet per second	0.028	cubic metres per second

F. TABLE OF IMPERIAL TO IMPERIAL CONVERSIONS

When you have _______________ multiply by _______________ to get

****

to get _______________ divide by _______________ when you have

miles	5280	feet
miles	1760	yards
acres	43,560	square feet
acre feet	43,560	cubic feet
acre feet	272,200	gallons
gallons	0.16	cubic feet
gallons	160	fluid ounces
pints	20	fluid ounces
gallons (water)	10	pounds
cubic feet (water)	62.4	pounds

G. RULES FOR WRITING METRIC SYMBOLS

Each unit of the Metric System contains a unique symbol:

m = metre

g = gram

L = litre

1. Metric symbols should be printed in roman, upright type. (Use of italicized or sloped type is restricted). NOTE: A number of countries are now adopting the upper case L as the preferred symbol for the litre, both when used alone and with a prefix, e.g. mL.

2. Symbols always appear in lower case letters except when the unit name is derived from a proper name.

   Examples: m = metre

   s = second

   A = ampere

   Wb = weber

3. Prefix symbols are printed in upright type without spacing between the prefix symbol and the unit symbol:

   kg for kilogram = kilo--prefix symbol; gram--unit symbol

   km for kilometre = kilo--prefix symbol; metre--unit symbol

4. Symbols should not be pluralized (-s) even when in the plural form: 1 g, 45 g (not 45 gs)

5. Metric symbols should always be written without a final, full stop (period) except at the end of a sentence.

6. Compound prefixes are not correct. Only one prefix can be used at a time.

7. Units should be written out when no number is involved. Otherwise symbols should be used when associated with a number:

    e.g. The floor's area is 12 m^2, not 12 square metres.
    Carpet is sold by the square metre, not by the m^2.

8. Decimals, not fractions should be used. e.g. 0.75 g (not 3/4 g).

9. Symbols should not be used to start a sentence.

10. A zero always precedes the decimal marker in a number less than zero. 0.45 g (not .45 g).

11. Square and cubic measures of area and volume must be written with an exponent ^{2} or ^{3} respectively: m^2, km^3, m^3, cm^2 (cc is incorrect).

REFERENCES

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"Five Days to Metric, Canada Department of Agriculture, Ottawa, 1976.

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EXCERCISES

1. How many m in 3.8 km? ______________________________

2. How many km in 470 m? ______________________________

3. How many m^2 in 2.8 ha? ______________________________

4. How many ha-m in 23,000 m^3? ______________________________

5. How many m^3 in 5 ha-m? ______________________________

6. How many L in 8 m^3? ______________________________

7. How many g in 0.6 kg? ______________________________

8. What weight is 20 L of water? ______________________________

9. How many m in 10 feet? ______________________________

10. How many ha in 100 acres? ______________________________

11. How many ha-m in 24 acre feet? ______________________________

12. How many L in 200 gallons? ______________________________

13. How many kg in 50 pounds? ______________________________

SOLUTIONS

1. 3800 m
2. 0.47 km
3. 28,000 m^2
4. 2.3 ha-m
5. 50,000 m^3
6. 8000 L
7. 600 g
8. 20 kg
9. 3 m
10. 40 ha
11. 3 ha-m
12. 900 L
13. 22.7 kg

ACTIVE INGREDIENT

Every herbicide product is made up of two main components - the chemical that actually kills or controls the growth of the plant, called the ACTIVE INGREDIENT (a.i.) and a non active agent which serves to dilute the active ingredient to a useable strength, called a CARRIER. Certain additives may be included which enhance the action of the active ingredient. These could take the form of wetting agents, stickers, emulsifiers, synergists, or activators.

The amount of active ingredient in a herbicide product is specified on the label as the guarantee. The amount is given as a percentage of the product or as a ratio (quantity of active ingredient per quantity of product eg. grams per litre, millilitre per litre).

ACTIVE INGREDIENT GIVEN AS A PERCENTAGE

If a product has 10% active ingredient, this means that every 100 parts of product will contain 10 of the same parts of active ingredient.

If product A contains 10% active ingredient, 100 kg of product A will contain 10 kg a.i.; 500 kg of product A will contain 50 kg a.i.; 1,000 kg of product A will contain 100 kg a.i.. Conversely 5 kg of a.i. will be present in 50 kg of product A; 20 kg of a.i. will be present in 200 kg of product A; 50 kg of a.i. will be present in 500 kg of product A.

$$\text{Total quantity of a.i.} = \frac{\text{a.i. percentage value (from label)}}{100} \times \text{quantity of product}$$

$$\text{Total quantity of product} = \frac{100}{\text{a.i. percentage value (from label)}} \times \text{total quantity of a.i.}$$

EXERCISES

1. The guarantee of product B is 5% a.i. How many kg of a.i. are in the following quantities of product B:

a) 10 kg product ______________________ kg a.i.

b) 25 kg product ______________________ kg a.i.

c) 150 kg product _____________________ kg a.i.

d) 500 kg product _____________________ kg a.i.

2. The guarantee of product C is 20% a.i. How many kg of product will contain the following quantities of a.i.:

a) 2 kg a.i. ________________________ kg product

b) 8 kg a.i. ________________________ kg product

c) 25 kg a.i. _______________________ kg product

d) 75 kg a.i. _______________________ kg product

ACTIVE INGREDIENT GIVEN AS A RATIO

If a product contains 500 g a.i. per litre this means that every litre of product will contain 500 g a.i.

If product D contains 500 g (0.5 kg) a.i. per L, 10 L of product D will contain 5 kg a.i.; 1000 L of product D will contain 500 kg a.i. Conversely, 1000 g (1 kg) of a.i. will be present in 2 L of product D; 5 kg a.i. will be present in 10 L of product D; 15 kg a.i. will be present in 30 L of product D.

Total quantity of a.i. = a.i. ratio (from label) x quantity of product.

Total quantity of product = inverse a.i. ratio x quantity of a.i.

EXERCISES

3. The guarantee of product E is 600 g a.i. per litre. How

many kilograms a.i. are in the following quantities of product E.

a) 5 L product ______________________ kg a.i.

b) 50 L product ______________________ kg a.i.

c) 500 L product ______________________ kg a.i.

d) 2000 L product ______________________ kg a.i.

4. The guarantee of product F is 200 g a.i. per litre. How many litres of product will contain the following quantities of a.i.:

a) 600 g a.i. ______________________ L product

b) 800 g a.i. ______________________ L product

c) 2 kg a.i. ______________________ L product

d) 10 kg a.i. ______________________ L product

For most herbicide applications, one does not need to know how to calculate quantity of active ingredient if label directions are closely followed. This is because most labels express rates of application in terms of quantity of product to apply.

It is helpful to know active ingredient calculations when comparing prices between different products having the same a.i., when referring to technical journals and government publications, and when applying herbicide mixtures.

SOLUTIONS

1.

a) $$\text{a.i.} = \frac{5}{100} \times 10\ \text{kg}$$

$$= 0.5\ \text{kg}$$

b) a.i. = $\frac{5}{100} \times 25$ kg

$= 1.25$ kg

c) a.i. = $\frac{5}{100} \times 150$ kg

$= 7.5$ kg

d) a.i. = $\frac{5}{100} \times 500$ g

$= 25$ kg

2.

a) product = $\frac{100}{20} \times 2$ kg

$= 10$ kg

b) product = $\frac{100}{20} \times 8$ kg

$= 40$ kg

c) product = $\frac{100}{20} \times 25$ kg

$= 125$ kg

d) product = $\frac{100}{20} \times 75$ kg

$= 375$ kg

3.

a) a.i. = $\frac{600 \text{ g}}{\text{L}} \times 5$ L

$= 3000$ g $= 3$ kg

b) a.i. = $\frac{600 \text{ g}}{\text{L}} \times 50$ L

$= 30{,}000$ g $= 30$ kg

c) a.i. = $\frac{600 \text{ g}}{\text{L}} \times 500$ L

$= 300{,}000 \text{ g} = 300 \text{ kg}$

d) $\text{a.i.} = \frac{600 \text{ g}}{\text{L}} \times 2000 \text{ L}$

$= 1{,}200{,}000 \text{ g} = 1200 \text{ kg}$

4.

a) $\text{product} = \frac{\text{L}}{200 \text{ g}} \times 600 \text{ g}$

$= 3 \text{ L}$

b) $\text{product} = \frac{\text{L}}{200 \text{ g}} \times 800 \text{ g}$

$= 4 \text{ L}$

c) $\text{product} = \frac{\text{L}}{200 \text{ g}} \times 2000 \text{ g } (2 \text{ kg})$

$= 10 \text{ L}$

d) $\text{product} = \frac{\text{L}}{200 \text{ g}} \times 10{,}000 \text{ g } (10 \text{ kg})$

$= 50 \text{ L}$

PARTS PER MILLION

Parts per million (ppm) is simply a convenient way to express the concentration of one substance in another when that one substance is in very small quantity compared to the other. One ppm is equal to one part of a substance in one million of the same parts of another substance. Part is either the weight or volume of the substance.

Add 1 kg of salt to 1,000,000 L of water. Instead of saying the concentration of salt in water is 1 kg per 1,000,000 kg (Note: 1,000,000 L of water weighs 1,000,000 kg - it is necessary to use identical units in ppm calculations) we use the more convenient term and say the concentration of salt is 1 ppm.

With herbicides, ppm refers to the concentration of active ingredient in the substance to which the herbicide is applied or added. The substance could be water, soil or plant matter. This term is used in chemical analysis, in technical journals, in some government publications, and on a few herbicide labels.

EXERCISES

1. The following amounts of active ingredient are added to 2,000,000 L of water in a reservoir. What is the resulting ppm concentration?

   a) 1000 g ______________________ ppm

   b) 20 kg ______________________ ppm

   c) 4 L ______________________ ppm

   d) 5000 mL ______________________ ppm

2. To achieve the following ppm concentrations in a 16,000,000 L dugout, how many kg of active ingredient should be added?

a) 2 ppm ______________________ kg

b) 10 ppm ______________________ kg

c) 3 ppm ______________________ kg

d) 1 ppm ______________________ kg

SOLUTIONS

1.

a) 1000 g in 2,000,000 L

= 1000 g in 2,000,000 kg - changed to equal units

= 1 kg in 2,000,000 kg

= 0.5 kg in 1,000,000 kg

= 0.5 ppm

b) 20 kg in 2,000,000 L

= 20 kg in 2,000,000 kg - changed to equal units

= 10 kg in 1,000,000 kg

= 10 ppm

c) 4 L in 2,000,000 L

= 2 L in 1,000,000 L

= 2 ppm

d) 5000 mL in 2,000,000 L

= 5 L in 2,000,000 L - changed to equal units

= 2.5 L in 1,000,000 L

= 2.5 ppm

2.

a) 2 ppm = 2 kg in 1,000,000 kg

= 32 kg in 16,000,000 kg

= 32 kg in 16,000,000 L

= 32 kg

b) 10 ppm = 10 kg in 1,000,000 kg

= 160 kg in 16,000,000 kg

= 160 kg in 16,000,000 L

= 160 kg

c) 3 ppm = 3 kg in 1,000,000 kg

= 48 kg in 16,000,000 kg

= 48 kg in 16,000,000 L

= 48 kg

d) 1 ppm = 1 kg in 1,000,000 kg

= 16 kg in 16,000,000 kg

= 16 kg in 16,000,000 L

= 16 kg

PPM EQUIVALENTS (CONCENTRATION IN WATER)

1 ppm = 10 kg per ha-m

= 1 g per m^3

= 1 mg (milligram) per L

= 10 L per ha-m

= 1 mL per m^3

CALCULATIONS FOR HERBICIDE APPLICATION

Calculations are made prior to a herbicide application so that the proper amount of a product can be applied correctly to the target weeds.

An applicator must know how much chemical is needed to do the job. He must also know the specifications to which his application method should be adjusted so that the chemical is correctly distributed over the area to be treated.

CALCULATING AMOUNT OF PRODUCT TO APPLY

All herbicide labels indicate the amount of product to apply in order to control a given weed or group of weeds. This is usually given as a rate of application which specifies the amount of product to apply per unit of area (land area or water surface area) or per unit of water volume. The amount of product to apply may also be given as a mixture ratio. In these cases a specified amount of product is mixed with a specified amount of water. The resulting solution (applied by spray gun) is used to thoroughly wet the vegetation.

The following calculations are used to determine the amount of product to apply.

Calculating amount of product to apply when the rate of application is based on area.

The area of a rectangular or square shape is obtained by multiplying the length of the shape by its width.

$A = L \times W$; A = area; L = length; W = Width

The area of a circular shape is obtained by squaring the radius an multiplying this value by 3.14. The radius is equal to 1/2 of the diameter of a circle.

$A = r^2 \times 3.14$; A = area; r = radius

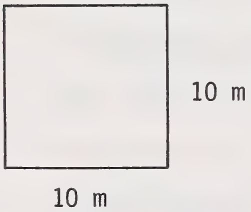
The area of an irregular shape such as that of a lake or slough, must be determined by analysis of maps, plans, or aerial photographs.

Area is most often expressed in terms of square metres (m^2) or hectares (ha).

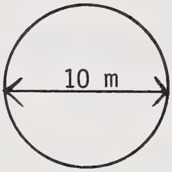
EXAMPLE CALCULATIONS

1. Determine the area in m^2 and ha for the following shapes:

a)



b)



a)

$$\begin{aligned} A &= L \times W \\ &= 10\ m \times 10\ m \\ &= 100\ m^2 \end{aligned}$$

$$\begin{aligned} ha &= \frac{m^2}{10,000} \\ &= \frac{100\ m^2}{10,000} \\ &= 0.01\ ha \end{aligned}$$

b)

$$\begin{aligned} A &= r^2 \times 3.14 \\ &= 5^2 \times 3.14 \\ &= 25\ m^2 \times 3.14 \\ &= 78.5\ m^2 \end{aligned}$$

$$\begin{aligned} ha &= \frac{m^2}{10,000} \\ &= \frac{78.5\ m^2}{10,000} \\ &= 0.00785\ ha \end{aligned}$$

The amount (quantity) of product to apply can be determined by multiplying the rate of application by the size of the area to be treated.

$Q = R \times A$;

Q = Quantity of product to apply
R = Rate of application (from label)
A = Area to be treated (calculated from measurements)

EXAMPLE CALCULATIONS

1. Art would like to treat his farm dugout with Reglone A to control Sago Pondweed and Elodea. Art reads the Reglone A label carefully and finds that to control these weeds he must apply 22.5 L of the product per surface hectare to water 1.5 m deep or less or 33.7 L of the product per surface hectare to water deeper than 1.5 m.

   Art's dugout has a water surface measuring 20 m long by 10 m wide. The deepest part of the dugout is 1.4 m deep. How much Reglone A should he apply to his dugout?

   a) Determine area (in hectares) to be treated.

$$A = L \times W = 20\ \text{m} \times 10\ \text{m} = 200\ \text{m}^2 \qquad \text{ha} = \frac{\text{m}^2}{10{,}000} = \frac{200\ \text{m}^2}{10{,}000} = 0.02\ \text{ha}$$

   b) Calculate quantity of product to apply.

$$Q = R \times A = \frac{22.5\ \text{L}}{\text{ha}}\ (\text{water under 1.5 m deep}) \times 0.02\ \text{ha} = 0.45\ \text{L}$$

   Answer: Art would apply 0.45 L of Reglone A to his dugout.

2. Joe would like to control a large patch of sow thistle on a ditchbank. The infestation covers the entire bank for a distance of 800 m. The width of the infestation measures 5 m. Joe chooses 2,4-D low volatile ester to treat the sow thistle. He reads the label and determines that the rate of application to use is 2.2 L of product per hectare. How much product should he apply to the sow thistle infestation?

   a) Determine area (in hectares) to be treated.

$$A = L \times W = 800\ \text{m} \times 5\ \text{m} \qquad \text{ha} = \frac{\text{m}^2}{10{,}000}$$

$$= 4000\ m^2 \qquad\qquad = \frac{4000\ m^2}{10,000} = 0.4\ ha$$

b) Calculate quantity of product to apply.

$$Q = R \times A$$
$$= \frac{2.2\ L}{ha} \times 0.4\ ha$$
$$= 0.88\ L$$

Answer: Joe would apply 0.88 L of product to the infestation.

Calculating amount of product to apply when the rate of application is based on water volume.

The volume of a body of water is obtained by multiplying it's surface area by it's average depth. V = A x D(ave); V = Volume; A = Surface Area; D(ave) = Average Depth

Volume is most often expressed as litres (L), cubic metres (m^3) or hectares metres (ha-m).

Average depth is derived by measuring the depth of a body of water in a number of locations and then averaging the values obtained. To arrive at an average, add up all measurements obtained and divide this value by the number of measurements taken.

EXAMPLE CALCULATIONS:

1. Determine the average depth, area, and water volume for the following:

2m	3m	3m	3m
1m	5m	5m	1m
1m	2m	2m	2m

25 m

20 m

= depth measurements

$$D(ave) = \frac{\text{sum of measurements}}{\text{number of measurements taken}}$$

$$= \frac{30\ \text{m}}{12}$$
$$= 2.5\ \text{m}$$

$$A = L \times W$$
$$= 25\ \text{m} \times 20\ \text{m}$$
$$= 500\ \text{m}^2$$

$$V = A \times D(\text{ave})$$
$$= 500\ \text{m}^2 \times 2.5\ \text{m}$$
$$= 1250\ \text{m}^3$$

The amount (quantity) of product to apply can be determined by multiplying the rate of application by the water volume.

$Q = R \times V$ V = water volume

EXAMPLE CALCULATIONS:

1. Sam wants to control a pond scum of filamentous algae. Deciding to use Princep 80W, Sam reads the label for directions. The label states that to control filamentous algae, apply 6 g of product per 10,000 L of water volume. Seeing that the product is applied per unit of volume, Sam goes out and measures the ponds length and width. He also measures the depth in a number of places. His results are diagrammed below.

	1m	2m	1m		
water surface	2m	4m	4m	5 m	= depth measurements
	1m	2m	1m		
		12 m			

How many grams of Princep 80W would Sam need to apply to his dugout?

a) Determine surface area, average depth, and from this, derive water volume in litres.

i. Surface Area

$$A = L \times W$$
$$= 12\ \text{m} \times 5\ \text{m}$$
$$= 60\ \text{m}^2$$

ii. Average Depth

$$D(ave) = \frac{\text{sum of measurements}}{\text{number of measurements taken}}$$

$$= \frac{18\ m}{9}$$

$$= 2\ m$$

iii. Water Volume

$$V = A \times D(ave)$$

$$= 60\ m^2 \times 2\ m$$

$$= 120\ m^3$$

Convert m^3 volume to litres -

$$L = m^3 \times 1000$$

$$= 120\ m^3 \times 1000$$

$$= 120{,}000\ L$$

b) Calculate quantity of product to apply.

$$Q = R \times V$$

$$= \frac{6\ g}{10{,}000\ L} \times 120{,}000\ L$$

$$= 72\ g$$

Answer: Sam would apply 72 grams of Princep 80W to his dugout.

Herbicides applied to plant foliage by spray gun (apply dilute mixtures to soak foliage).

With these products you must estimate the amount of spray solution needed to thoroughly wet all plants in an infestation. Calculate amount of product required by using the mixture rates specified on the label.

EXAMPLE CALCULATION:

1. Dale would like to control cattails that are plugging a drainage ditch. Deciding to use Dowpon, he reads the label and learns that he should add 2 kg of product to 100 L of water and apply with a spray gun to thoroughly wet all of the cattails. He estimates that he will need 800 L of spray solution to cover all cattails. How much product will he need to apply?

Spray mixture = 2 kg per 100 L
Volume needed = 800 L

$$\frac{2\text{ kg}}{100\text{ L}} = \frac{x\text{ kg}}{800\text{ L}}$$

$x = 16$ kg

Answer: Dale would require 16 kg of Dowpon added to 800 L of water in order to treat the cattail infestation.

CALCULATING HOW TO APPLY

Once you know the quantity of product to apply, the next step is to determine how to apply that quantity evenly over the target area.

PRODUCT DILUTION

It is normally recommended that the product be mixed with water in the spray tank to provide a dilute spray solution. This addition of water makes it easier to distribute the product over a large area and also allows for better coverage of the target vegetation (this is essential for applications made to plant foliage). The label may indicate how much water to use, for example it may tell you to apply x litres of product in y litres of water per hectare. The amount of water required per hectare will ultimately equal the amount of spray solution used per hectare.

To calculate the amount of spray solution required, multiply the amount of water needed per hectare by the number of hectares to be treated. Add to the tank, the quantity of product required, then add the water until the calculated amount of spray solution is achieved.

EXAMPLE CALCULATION:

1. Al wants to spray a 5 ha area with 2,4-D. The rate of application stated on the label is 2 L of product in 100 L of water per hectare. How would Al make up his spray solution?

a) Determine the quantity of product to apply.

$$\begin{aligned} Q &= R \times A \\ &= \frac{2\ \text{L}}{\text{ha}} \times 5\ \text{ha} \\ &= 10\ \text{L} \end{aligned}$$

b) Quantity of (spray solution).

$$Q_S = R_W \times A$$

Q_S = Quantity of spray solution required

R_W = Rate of water required per unit area

A = Area

$$\begin{aligned} Q_S &= \frac{100\ \text{L}}{\text{ha}} \times 5\ \text{ha} \\ &= 500\ \text{L} \end{aligned}$$

Answer: Al would first add the necessary 10 L of product to the tank. He would then fill the tank up to the 500 L mark with water. This 500 L of spray solution would be used to treat Al's 5 ha area.

CALCULATIONS FOR ADJUSTMENT OF APPLICATION METHOD

Five important aspects of a herbicide application must be known.

Sprayer output (O) - the quantity of spray solution delivered by your application equipment in a fixed period of time.

Travelling speed (S) - the speed at which you will travel over the area to be treated.

Quantity of spray solution (Q_S) - the total amount of product plus water needed to treat the area.

Swath width (W) - the width of coverage made by a single pass of the application equipment.

Amount of area to be treated (A)

To obtain even coverage of the area to be treated you will have to adjust your method of application appropriately. For example, if you know the output and swath width of your equipment, the quantity of spray solution and the amount of area to be treated, you can adjust your travelling speed to ensure even application of the chemical.

You can adjust, within certain limits either sprayer output, travelling speed, or the quantity of spray solution. You will need to determine what these adjustments should be before proceeding. The following formulae can be used.

Sprayer output in $\frac{\text{litres}}{\text{minute}}$ (O) $= \dfrac{S(\frac{km}{hr}) \times W\,(m) \times Q_s\,(L)}{A(ha) \times 600}$

Travelling speed in $\frac{\text{kilometres}}{\text{hour}}$ (S) $= \dfrac{O(\frac{L}{min}) \times A\,(ha) \times 600}{W\,(m) \times Q_s\,(L)}$

Quantity of spray solution in litres (Q_s) $= \dfrac{O(\frac{L}{min}) \times A(ha) \times 600}{W\,(m) \times S(\frac{km}{hr})}$

EXAMPLE CALCULATION:

1. Mike wants to spray a ditchbank with 2,4-D. The ditchbank measures 3 m wide by 4,000 m long. The 2,4-D label tells Mike to apply 2 L of product in 100 L of water per hectare. Mike's equipment can cover a width of 3 m. He can travel easily at 9 km per hour along the ditchbank. To what output should Mike adjust his sprayer in order to cover the entire ditchbank in one pass?

   a) Calculate area to be treated (in hectares).

$$A = L \times W = 4{,}000\ \text{m} \times 3\ \text{m} = 12{,}000\ \text{m}^2$$

$$\text{ha} = \frac{\text{m}^2}{10{,}000} = \frac{12{,}000\ \text{m}^2}{10{,}000} = 1.2\ \text{ha}$$

b) Calculate quantity of spray solution (Q_s).

$$Q_s = R_w \times A$$

$$= 100\ \frac{\text{L}}{\text{ha}} \times 1.2\ \text{ha}$$

$$= 120\ \text{L}$$

NOTE: Quantity of spray solution per hectare equals the amount of water required per hectare.

c) Determine sprayer output (O).

$$O = \frac{S \times W \times Qs}{A \times 600}$$

$$= \frac{9\ \frac{\text{km}}{\text{hr}} \times 3\ \text{m} \times 120\ \text{L}}{1.2\ \text{ha} \times 600}$$

$$= 4.5\ \frac{\text{litres}}{\text{minute}}$$

Answer: Mike would adjust his sprayer to deliver 4.5 L of spray solution per minute.

2. Fred is going to treat a 2 ha reservoir with Reglone A. He knows that his boat mounted equipment will deliver 5 L of spray solution per minute over a width of 2 m. Following the label, Fred mixes 1 part of the required product to 10 parts clean water in the tank (application rate = 22.5 L product per surface hectare). How fast should he drive his boat during application in order to cover the reservoir with all of the spray solution?

   a) Calculate quantity of spray solution (Q_s).

   Quantity of product required = R x A

$$= 22.5 \ \frac{L}{ha} \times 2 \text{ ha}$$

$$= 45 \text{ litres product}$$

Spray solution contains 1 part product in 10 parts water, therefore, 45 litres product in 450 L water.

Quantity of spray solution will equal 450 L.

b) Determine travelling speed (S).

$$S = \frac{Q \times A \times 600}{W \times Q_s}$$

$$= \frac{5 \ \frac{L}{min} \times 2 \text{ ha} \times 600}{2 \text{ m} \times 450 \text{ L}}$$

$$= 6.7 \ \frac{km}{hr}$$

Answer: Joe would drive his boat at 6.7 km/hr.

3. Joe wants to spray cattails in a drainage ditch by use of a spray gun. The cattails cover an area 2 m wide by 500 m long. The herbicide label recommends mixing 2 kg of product in 100 L of water and spraying this mixture to thoroughly wet foliage. The output of the gun is measured at 10 L per minute. Joe figures that if he walks along the ditch at a speed of 10 m per minute while spraying, he can wet all of the foliage. (NOTE: the swath width would equal the width of the cattail infestation - 2 m). How much spray solution would Joe need to treat all of the cattails and how much product would he require?

a) Determine area (A) to be treated in hectares.

$$A = L \times W$$

$$= 500 \text{ m} \times 2 \text{ m}$$

$$= 1000 \text{ m}^2$$

$$\text{ha} = \frac{m^2}{10{,}000}$$

$$= \frac{1{,}000 \text{ m}^2}{10{,}000}$$

$$= 0.1 \text{ ha}$$

b) Determine travelling speed in km/hr.

$$\frac{10 \text{ metres}}{1 \text{ minute}} = \frac{600 \text{ metres}}{60 \text{ minutes}} \text{ (1 hr.)}$$

$$\frac{600 \text{ metres}}{\text{hr}} = \frac{0.6 \text{ km}}{\text{hr}}$$

c) Calculate quantity of spray solution (Q_s) required.

$$Q_s = \frac{0 \times A \times 600}{W \times S}$$

$$= \frac{10 \frac{\text{L}}{\text{min}} \times 0.1 \text{ ha} \times 600}{2 \text{ m} \times 0.6 \frac{\text{km}}{\text{hr}}}$$

$$= 500 \text{ litres}$$

d) Calculate quantity of product required.

Mixture ratio (from label) $= \frac{2 \text{ kg product}}{100 \text{ L water}}$

$$\frac{2 \text{ kg product}}{100 \text{ L water}} = \frac{x \text{ kg product}}{500 \text{ L water}}$$

$x = 10$ kg product

Answer: Joe would need 500 L of spray solution. The spray solution would contain 10 kg of product.

EXERCISES

1. How many L of product would one need in order to treat a 2 ha reservoir? The rate of application stated on the label is 6 L in 100 L of water per surface ha.

2. A rectangular pond measures 100 m long by 70 m wide. The average depth is 4 m. How much product would be needed to treat the entire pond at a rate of application of 5 kg per ha-m?

3. A circular pond has a diameter of 10 m. The average depth is 150 cm. How much product is needed to treat the entire pond at a rate of application of 20 g per 1000 m^3?

4. A ditch measuring 1000 m long by 2 m wide is completely covered with cattail. It will take 2000 L of spray solution to completely soak the vegetation. At a mixture ratio of 2 kg of product per 100 L of water, how much product is needed to treat the cattails?

5. A travelling speed of 10 km per hour is used by a sprayer treating a ditchbank. The width being sprayed is 2 m. The length of ditchbank to be treated is 3 km, while the width of the ditchbank is 2 m. At a rate of application of 20 L product in 100 L of water per hectare, what would the output (in L/min.) of the sprayer be adjusted to so that the entire ditchbank is treated in one pass?

6. A rectangular patch of cattail measures 20 m wide by 50 m long. Walking at a speed of 1 km per hour an applicator can cover a width of 5 m with a spray gun and be able to soak all of the vegetation. The prescribed spray solution contains 3 kg of product per 100 L of water. With a sprayer output of 10 L per minute, how much product is needed to treat the entire patch of cattails?

7. A boat bailer delivers 10 L of a chemical solution per minute over an effective swath width of 3 m. In order to treat a 4 ha lake at a rate of 10 L of product in 100 L of water, a total of 400 L of spray solution is required. The spray tank mounted in the boat will hold only 100 L of solution; therefore only 1/4 of the lake area can be treated per tankload. How fast would one drive the boat in order to treat that one quarter of the lake area?

SOLUTIONS

1. $Q = R \times A$

$= \frac{6 \text{ L} \times 2 \text{ ha}}{\text{ha}}$

$= 12 \text{ L}$

2. a. determine area

$A = L \times W$

$= 100 \text{ m} \times 70 \text{ m}$

$= 7000 \text{ m}^2$

b. determine water volume in ha-m

$V = A \times D(\text{ave})$

$= 7000 \text{ m}^2 \times 4 \text{ m}$

$= 28000 \text{ m}^3$

$10{,}000 \text{ m}^3 = 1 \text{ ha-m}$

$28{,}000 \text{ m}^3 = 2.8 \text{ ha-m}$

c. determine quantity of product to apply

$Q = R \times V$

$= \frac{5 \text{ kg}}{\text{ha-m}} \times 0.28 \text{ ha-m}$

$= 14 \text{ kg}$

3. a. determine area

$A = r^2 \times 3.14$

$= 5^2 \times 3.14$

$= 78.5 \text{ m}^2$

b. determine water volume in m^3

$V = A \times D(\text{ave})$

$= 78.5 \text{ m}^2 \times 1.5 \text{ m}$

$= 117.75 \text{ m}^3$

c. determine quantity of product to apply

$Q = R \times V$

$= \frac{20\ g}{1000\ m^3} \times 117.75\ m^3$

$= 2.35\ g$

4. $\frac{2\ kg}{100\ L} = \frac{x\ kg}{2000\ L}$

$x = 40\ kg$

5. a. determine area to be treated (in hectares)

$A = L \times W$

$= 3000\ m \times 2\ m$

$= 6000\ m^2$

$10,000\ m^2 = 1\ ha$

$6,000\ m^2 = 0.6\ ha$

b. determine quantity of spray solution

$Q_s = R_w \times A$

$= \frac{100\ L}{ha} \times 0.6\ ha$

$= 60\ L$

c. determine sprayer output

$O = \frac{S \times W \times Qs}{A \times 600}$

$= \frac{10\ \frac{km}{hr} \times 2\ m \times 60\ L}{0.6\ ha \times 600}$

$= 3.3\ \frac{L}{min}$

6. a. determine area to be treated (in hectares)

$A = L \times W$

$= 20\ m \times 50\ m$

$$= 1000 \text{ m}^2$$

$$10{,}000 \text{ m}^2 = 1 \text{ ha}$$

$$1{,}000 \text{ m}^2 = 0.1 \text{ ha}$$

b. determine quantity of spray solution required

$$Q_s = \frac{O \times A \times 600}{W \times S}$$

$$= \frac{10 \frac{\text{L}}{\text{min}} \times 0.1 \text{ ha} \times 600}{5 \text{ m} \times 1 \frac{\text{km}}{\text{hr}}}$$

$$= 120 \text{ L}$$

c. determine quantity of product required

$$\frac{3 \text{ kg}}{100 \text{ L}} = \frac{x \text{ kg}}{120 \text{ L}}$$

$$x = 3.6 \text{ kg}$$

7.

$$S = \frac{O \times A \times 600}{W \times Q_s}$$

$$= \frac{10 \frac{\text{L}}{\text{min}} \times 1 \text{ ha} \times 600}{3 \text{ m} \times 100 \text{ L}}$$

$$= 20 \frac{\text{km}}{\text{hr}}$$

APPENDIX 2

GLOSSARY OF TERMS

ABSORPTION - movement of a chemical into a plant, animal or the soil

ACTIVATED CHARCOAL - finely ground, high quality charcoal which adsorbs liquids and gases easily

ACTIVE INGREDIENT (a.i.) - that part of the pesticide mixture which is directly responsible for killing insects, weeds and other pests

ACUTE DERMAL TOXICITY - poisoning from a single dose of a chemical absorbed through the skin

ACUTE ORAL TOXICITY - poisoning from a single dose of a chemical taken by mouth

ACUTE POISONING - poisoning produced by a single exposure, or a few repeated exposures to excessive amounts of a toxic material

ADJUVANT - something when added to the pesticide mixture makes the active ingredient more effective, eg. wetting agent, spreader, adhesive, emulsifying agent, penetrant

ADSORPTION - attachment of a substance on the surface of another substance

ANNUAL - a plant that germinates from seed, produces seed and dies in the same year

ANNUAL, WINTER - a plant from late summer germinating seed, plant blooms and fruits the next season

AXIL - space formed by the angle between a leaf or branch and the stem

BASAL TREATMENT - application of a chemical at the base of a plant or just above the ground level

BIENNIAL - a plant which completes its entire life cycle in two years. The first year it produces leaves and stores food

BOOM - several nozzles joined together by sections of pipe or tubing to apply pesticides over a wider area at one time

BROADLEAVED PLANTS - most herbs, shrubs and trees having wide, flat, leaves and netted veins

CALIBRATE - to adjust to a standard to determine the amount of pesticide being applied through a nozzle of a sprayer, duster or granular applicator over a given area

CARRIER - the liquid or solid material added to a chemical compound to facilitate its application in the field

CHEMICALLY INACTIVE - will not react with any other chemical or object, eg. talc, clay

CHLOROPHYLL - the green compound in leaves and other plant parts responsible for photosynthesis (the means by which the plant converts water and carbon dioxide of the air into food through the energy of the sunlight)

CHRONIC POISONING - poisoning resulting from cumulative damage by a toxic material over a long period of time, usually following prolonged or repeated contact with the material

COMPATIBLE PESTICIDES - compounds or formulations that can be mixed and applied together without reducing their separate effects or harming the crops

CONTACT HERBICIDE - one that kills primarily at the site of contact with plant tissue rather than as a result of translocation

CONTAMINATE - the addition of an unwanted material such as a pesticide where it can cause harm or damage

CREEPING RHIZOME - a rhizome growing on or near the soil surface

DECIDUOUS - plants which lose their leaves during the dormant winter months

DECONTAMINATE - to render a material harmless by removing or breaking down the unwanted material (usually a pesticide)

DEFOLIANT - a pesticide which causes leaves of a plant to drop off

DESICCANT - a pesticide which draws moisture from a plant or plant part causing the leaves to wither and die

DILUENT - any liquid or solid material that dilutes an active ingredient in the preparation of a formulation

DORMANT - period of time in which seeds and other plant parts are not growing

DORMANT SPRAY - pesticide spray applied during the winter and early spring when plants are dormant

DRIFT - the movement, by wind or air currents of droplets, or particles of the pesticide from the target area to an area not intended for treatment

DUST - a finely ground, dry mixture containing a small amount of pesticide and an inert carrier such as talc anc clay. Dust particles come in many different sizes

EMETIC - something that causes vomiting to get rid of poison in the stomach

EMULSIFIABLE CONCENTRATES - usually liquids in which the chemical is dissolved in one or more solvents such as oil or benzene to which an emulsifier is added

EMULSIFIER - a chemical which aids one liquid in forming tiny droplets, enabling that liquid to mix in another liquid. Its use includes forming stable mixtures which normally would not mix, eg. oil and water

EMULSION - a mixture of two or more immiscible liquids, such as oil and water where one is suspended or dispersed in the other in the form of very minute droplets and remains suspended or dispersed for a period of time

FLOWABLE - very finely ground solid materials which are mixed in a liquid carrier

FOLIAR APPLICATION - pesticides applied to the stems, leaves, needles, or blades of plants

FORMULATION - a mixture of one or more active pesticides and materials such as carriers, diluents, etc. needed to make it safe and easy to store, dilute and apply

GRANULAR - a formulation of relatively course particles which are applied dry with a spreader or seeder

GROWTH REGULATOR - a pesticide which increases, decreases or changes the normal growth and behavior of a plant

HYDROSOIL - soil covered by water

INCOMPATIBLE - not able to be mixed or used together. When two or more pesticides that are not compatible are mixed together, the effectiveness of one or more may be reduced or injury to plants or animals may result

INVERT EMULSION - one in which the water is dispersed in oil rather than oil and water. Oil forms the continuous phase with the water dispersed herein (eg. mayonaise)

LD_{50} - the number of milligrams of a toxicant per kilogram of body weight of an animal sufficient to kill 50% of a test population. The lower the LD_{50} value, the more poisonous the toxicant. LD_{50} values are commonly used to determine comparative acute oral and acute dermal toxicity, for pesticides

LEACHING - movement of a substance in solution through the soil

MISCIBLE - liquids capable of being mixed

NECROSIS - the death of localized patches of plant tissue

NODE - a level on the stem from which leaves or roots may arise

NON-SELECTIVE HERBICIDE - a herbicide that will kill all plants

ORGANISM - any living thing (plant, animal, fungus, bacteria, insect, etc.)

PERENNIAL - a plant which persists from year to year. The tops may die back, but the roots persist. Perennials include trees and shrubs, and many weeds

PESTICIDE - any substance or mixture of substances intended for killing or controlling all forms of plant or animal life that are considered to be pests

PESTICIDE DEALER - a firm that holds a valid licence to retail pesticides

PESTICIDE RESIDUE - deposit which remains in or on soil or plant matter following application of a pesticide

PHOTOSYNTHESIS - the process, in plants, by which carbohydrates are manufactured from carbon dioxide and water. Sunlight is used as an energy source

pH - the degree of acidity or alkalinity of a substance measured on a scale of 1-14. A pH value of 7 is the neutral point being neither acid or alkaline. pH values below 7 indicate acidity and those above indicate alkalinity

PHYTOTOXICITY - the injury or poisoning of plant life as a result of chemicals or other agents

PLANKTONIC - suspended in the water column

POST-EMERGENCE TREATMENT - treatments made after weeds emerge through the soil surface

PRE-EMERGENCE TREATMENT - treatment prior to emergence of the target weed

RESIDUAL PESTICIDE - chemical sprays or dusts that remain active in the soil for a long while after application

RHIZOME - an underground stem

RUNNER - a horizontal branch extending along the ground and giving rise to new roots and shoots

SELECTIVE PESTICIDE - chemical which will control only a few pest species and is not as poisonous to other plants and animals

SENSITIVE CROPS - crops which could easily be injured by pesticides, even by slight exposure

SLURRY - watery mixture or suspension of an insoluble pesticide to the consistency of a slow-running paste

SPIKE - a group of flowers growing close together on a longitudinal axis

SOIL APPLICATION - application of a pesticide primarily to the soil surface rather than to vegetation

SOLUBLE POWDER - a finely ground, solid pesticide that will dissolve in water or another liquid

SOLUBILITY - the amount of a substance which will dissolve in a given amount of another substance

SOLUTION - a mixture made by dissolving a solid, liquid or gas in a liquid. The mixture will not separate or settle out in normal use

SOLVENT - a liquid such as water, oil or kerosene used to dissolve other materials

SPOT TREATMENT - application of a pesticide to individual plants, small clumps of plants or localized and restricted areas

SPREADER-STICKER - substance added to a pesticide which makes spray droplets spread apart and adhere better to the treated surface

SURFACTANT - chemical or agent used in a pesticide to enhance mixing, spreading or wetting properties eg. emulsifier, wetting agent, spreader-stickers

SUSCEPTIBLE - injury or death may occur by the pesticide at the rates used

SUSPENSION - mixture in which fine particles of a solid are usually dispersed in a liquid

SYNERGIST - another chemical added to a pesticide mixture which makes the pesticide more poisonous than before it was added

SYSTEMIC PESTICIDE - a pesticide taken up by one part of a plant or animal and moved to another section where it acts

TERMINAL - at the end of a stem, branch or root

TOXICITY - the degree to which a substance is injurious to a plant or animal

TRANSLOCATION - internal transfer of materials from one part of a plant to another, via the plant's vascular system

TUBER - a thickened underground branch capable of producing new plants

VAPOR DRIFT - vapor movement away from the area of application

WEED - an unwanted plant

WETTABLE POWDER - a pesticide formulation of powder which is mixed with water to be applied. It does not dissolve in water but forms a suspension

WETTING AGENT - an additive which helps the pesticide spread out to cover a surface more uniformly

WINTER BUD - a small hardened close grouping of leaves surviving the plant over winter and capable of producing a new plant in spring

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